DEPARTMENT OF EDUCATION

FOR THE

UNITED STATES COMMISSION TO THE PARIS EXPOSITION OF 1900

MONOGRAPHS ON EDUCATION

IN THE

UNITED STATES

EDITED BY

NICHOLAS MURRAY BUTLER

Professor of Philosophy and Education in Columbia University, New York

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11

SCIENTIFIC, TECHNICAL AND ENGINEERING EDUCATION

BY

T. C. MENDENHALL,

President of the Technological Institute, Worcester, Mass.

THIS MONOGRAPH IS CONTRIBUTED TO THE UNITED STATES EDUCATIONAL EXHIBIT BY THE STATE OF NEW YORK

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Director
HOWARD J. ROGERS, Albany, N. Y.

MONOGRAPHS
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1 EDUCATIONAL ORGANIZATION AND ADMINISTRATION — ANDREW SLOAN DRAPER, *President of the University of Illinois, Champaign, Illinois*

2 KINDERGARTEN EDUCATION — SUSAN E. BLOW, *Cazenovia, New York*

3 ELEMENTARY EDUCATION — WILLIAM T. HARRIS, *United States Commissioner of Education, Washington, D. C.*

4 SECONDARY EDUCATION — ELMER ELLSWORTH BROWN, *Professor of Education in the University of California, Berkeley, California*

5 THE AMERICAN COLLEGE — ANDREW FLEMING WEST, *Professor of Latin in Princeton University, Princeton, New Jersey*

6 THE AMERICAN UNIVERSITY — EDWARD DELAVAN PERRY, *Jay Professor of Greek in Columbia University, New York*

7 EDUCATION OF WOMEN — M. CAREY THOMAS, *President of Bryn Mawr College, Bryn Mawr, Pennsylvania*

8 TRAINING OF TEACHERS — B. A. HINSDALE, *Professor of the Science and Art of Teaching in the University of Michigan, Ann Arbor, Michigan*

9 SCHOOL ARCHITECTURE AND HYGIENE — GILBERT B. MORRISON, *Principal of the Manual Training High School, Kansas City, Missouri*

10 PROFESSIONAL EDUCATION — JAMES RUSSELL PARSONS, *Director of the College and High School Departments, University of the State of New York, Albany, New York*

11 SCIENTIFIC, TECHNICAL AND ENGINEERING EDUCATION — T. C. MENDENHALL, *President of the Technological Institute, Worcester, Massachusetts*

12 AGRICULTURAL EDUCATION — CHARLES W. DABNEY, *President of the University of Tennessee, Knoxville, Tennessee*

13 COMMERCIAL EDUCATION — EDMUND J. JAMES, *Professor of Public Administration in the University of Chicago, Chicago, Illinois*

14 ART AND INDUSTRIAL EDUCATION — ISAAC EDWARDS CLARKE, *Bureau of Education, Washington, D. C.*

15 EDUCATION OF DEFECTIVES — EDWARD ELLIS ALLEN, *Principal of the Pennsylvania Institution for the Instruction of the Blind, Overbrook, Pennsylvania*

16 SUMMER SCHOOLS AND UNIVERSITY EXTENSION — HERBERT B. ADAMS, *Professor of American and Institutional History in the Johns Hopkins University, Baltimore, Maryland*

17 SCIENTIFIC SOCIETIES AND ASSOCIATIONS — JAMES MCKEEN CATTELL, *Professor of Psychology in Columbia University, New York*

18 EDUCATION OF THE NEGRO — BOOKER T. WASHINGTON, *Principal of the Tuskegee Institute, Tuskegee, Alabama*

19 EDUCATION OF THE INDIAN — WILLIAM N. HAILMANN, *Superintendent of Schools, Dayton, Ohio*

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SCIENTIFIC, TECHNICAL AND ENGINEERING SCHOOLS[1]

The development of the schools of science and technology in the United States is, practically, an affair of the last half of the nineteenth century. In a large measure the same is true of similar institutions in Europe, for although there are isolated examples of earlier foundations both in Europe and America, it is only during the past fifty years that in number and importance they have come to rank with older systems of intellectual and professional training. Their comparatively recent origin is readily accounted for when it is remembered that they are nearly all schools in which science is taught with a view to its practical application and that the admission to the college curriculum of any part of what is now generally included under the term "science" was a rare novelty in the early part of the century. The modern scientific school or engineering college is largely indebted for its being to Archimedes, Galileo, Bacon, Kepler, Newton and a host of others who by creating exact science made applied science possible. The idea of a *school* of science or of a college in which the applications of scientific discovery might be taught was of slow growth at the beginning, and naturally so, for their successful development demanded the evolution of methods of instruction entirely new and often in violation of accepted tradition.

A class of professional schools had existed, indeed, almost as long as education itself, namely, schools for training candidates for the so-called "learned" professions, law, medicine and theology, but it will not be claimed that they had much

[1] The author begs to express his appreciation of the assistance generously rendered by officers of many of the institutions referred to in this paper who kindly furnished information in the form of printed circulars, catalogues and other important publications, much of which he has made use of, and much more of which he would have gladly used had the limits of space permitted.

in common, either as to method or material, with the modern school of science.

The earliest technical schools, those of a hundred years ago or more, almost without exception grew out of the industrial demands of the locality in which they were founded. One of the best examples is the famous School of mines at Freiberg which has enjoyed a long and illustrious career and many of the earlier European schools belong to the same class. To these and the more modern schools of science and technology the United States is greatly indebted, especially on account of the generous welcome that has always been extended to American students and for the inspiration with which many of them have returned to take their part in the wonderful educational evolution which the last half century has witnessed.

But in all cases European methods have been adapted rather than adopted. Political, social and material conditions have largely influenced educational foundations, and while the nearly one hundred schools of science and engineering scattered over the United States have many points of resemblance, there is much individuality, particularly among the strongest and best, and it is believed that their several types represent important advances in the direction of scientific and technical education which will not be without interest to educators in other parts of the world.

The limit necessarily put upon the length of this paper makes it impossible to consider historically or otherwise all of the institutions which would properly come under its title. A not very exact classification based on organization easily divides all into three groups, and the end in view will be best accomplished by selecting for more careful description some of the more important representatives of each group. The order of presentation will be, in the main, chronological according to the date of establishment, and this will be departed from only when necessary to include the leading types of the several groups.

In the first group will be included those schools and col-

leges devoted practically exclusively to science and technology, which have independent foundations and which are not under state or government control. These have almost invariably originated in private endowment, often of one man, and rely for their support upon the income from their endowment and from tuition fees.

The second group embraces those schools which are closely affiliated with other colleges or schools forming universities, sometimes without a distinctly separate faculty or special organization, whose work has been largely individualized, sometimes having a distinguishing name, and not under state or government control. Some members of this group are wholly or partly supported by separate endowments and fix and collect their own tuition fees, while others depend upon sharing the common resources of the larger whole of which they are a part.

In the third group are included that very large and important class of schools supported largely, if not entirely, by state and government appropriation.

The organization of some of these resembles in an important particular that of the first group in the fact that they enjoy a separate existence as schools of science or technology, being independent of any college or university affiliation. The majority, however, are not thus independent, and must be regarded as departments of a college, or schools or colleges of a university. A few of them originated in private endowments and do not rely entirely on the state or national government for support, but yet are so largely dependent on that source of revenue that they fairly belong to the group. Something of the origin, history and development of a few of the principal representatives of these three groups will be given, to be followed by some general statements relating to requirements for admission, courses of study, degrees and other matters of interest or importance.

The first endowment and organization of a school of science in the United States was that of the **Rensselaer**

polytechnic institute in 1824. The founder, Stephen Van Rensselaer, was born in New York November 1, 1765, and died in Albany January 26, 1839. He was known as the "eighth patroon," having inherited his rank and estates from ancestors who had for generations ruled over that enormous feudal estate purchased and colonized early in the 17th century by Killian Van Rensselaer of Amsterdam, Holland. Stephen Van Rensselaer lost his baronial rights on the establishment of the colonial government during the revolutionary war, and the extent and value of the estate, which included the entire territory now comprised in the counties of Albany, Columbia and Rensselaer, were considerably diminished, but after graduating from Harvard college, he took active steps looking to the improvement of the very large property still remaining, and also rapidly became a prominent figure in the politics of the new nation, being in many ways peculiarly fitted for public duties and responsibilities. His early interest in engineering is proved by the fact that he was the first to propose a canal connecting the Hudson river with the great lakes. As a commissioner of the state, he made a personal investigation of the route, and in 1811 a report which was received with favor. The war of 1812 with Great Britain intervening to postpone action upon this important enterprise, he entered the military service as commander of the United States forces on the northern frontier. At the close of the war he again took hold of the canal project and became chairman of the canal commission. In the discharge of his duty as such, he caused to be made by Professor Amos Eaton in 1821–23, a geological survey along the line of the canal from Albany to Buffalo, the examination being also extended some distance into Massachusetts. The importance of the results of this work so impressed itself upon him, together with the lack of men capable of properly conducting such enterprises, as to convince him of the desirability and necessity for scientific and technical education. Professor Eaton, who executed this early geological survey for Van Rensselaer, was a man of many

and varied accomplishments, ready to adapt himself to the conditions under which his work was done, and possessed of much ingenuity and skill in inventing and constructing simple devices for taking the place of more elaborate but inaccessible instruments. Such a man was likely to make an impression upon the patroon, who was himself a man of liberal education and broad views. It is to this combination that the Rensselaer polytechnic institute owes its origin. Professor Eaton, its first director, was a native of the state of New York, born in 1776. When fourteen or fifteen years of age, having acted as chainman during a land survey, he determined to become a surveyor. He negotiated with a skillful blacksmith who agreed to work for him at night if he would "blow and strike" during the day. A needle and a good working chain resulted and an old pewter plate, smoothed, polished and graduated, served as a compass circle. At the age of 16 years he did actual surveying with these instruments. Later he entered Williams college and was graduated in 1799. His love for science led him to Yale college in 1815, where he received instruction from Professor Silliman. He gave courses of lectures at Williams college in 1817, developing a remarkable talent for popular exposition of scientific discovery, which resulted in his giving a course of lectures before the members of the New York legislature in 1818 on the invitation of Governor De Witt Clinton, and eventually in the geological survey already referred to at the request of Van Rensselaer. In his first letter to those selected to constitute the board of trustees Van Rensselaer named Professor Eaton as professor of chemistry and experimental philosophy, his office to be designated the "senior professorship."

This was dated November 5th, 1824, and something of the founder's idea of what his school ought to do is shown in "Order 7" of the same communication. He says: "These are not to be taught by seeing experiments and hearing lectures, according to the usual method. But they are to lecture and experiment by turn, under the immediate

direction of a professor or competent assistant. Thus by a term of labor, like apprentices to a trade, they are to become operative chemists." The opening of the school occurred on Monday, January 3rd, 1825. It was incorporated in March, 1826, the act providing that the clear annual income of the invested funds of the institution should *not exceed twenty thousand dollars.* It was at first named the "Rensselaer school;" afterward the "Rensselaer institute" and afterwards the "Rensselaer polytechnic institute." Professor Eaton served for seventeen years as the senior professor, and during this period the course of study covered only one year. An important epoch in the history of the institution was the appointment of Professor B. Franklin Greene as senior professor in 1846, who became director on the establishment of that office in 1850. From that time the institute became more distinctly a school of civil engineering. The course of study was lengthened to three years and the corps of instructors was enlarged. The buildings and much of the equipment were destroyed by fire in 1862, but they were replaced by friends of the school and more extensive equipment was provided.

The Rensselaer polytechnic institute offers two courses of four years each, one in civil engineering and one in natural science. Upon those who complete the first it bestows the degree of C. E., and for the second that of B. S. In 1899 its instructors were fifteen in number and its students 143. It has graduated 1219 men, of whom 874 are living. Being the first school of its kind its list of graduates doubtless excels all others in the number of men who have reached distinction in professional life. It is supported by the income from its endowment funds and by tuition fees. Its government is rested in a board of twenty trustees, with the mayor of the city of Troy, *ex-officio.*

The next in order of time and one of the foremost in the country is the **Massachusetts institute of technology** at Boston.

This now famous institution owes its existence to the wise

foresight, the earnest and never-flagging enthusiasm, and the rare personal charm of Professor William B. Rogers, its first president and real founder. Professor Rogers was born in Philadelphia in 1804, his father, Dr. Patrick K. Rogers, having emigrated from Ireland a few years earlier. In 1819 Dr. P. K. Rogers became professor of natural philosophy in William and Mary college, Virginia, and there Professor W. B. Rogers was educated. At an early age he was distinguished for his scientific attainments and for an eloquent and persuasive speech which greatly increased his influence among men. For a long time he was professor of natural philosophy in the University of Virginia and he also served as state geologist for many years. It was while still a professor in the university that his mind was turned to the problem of scientific and technical training, and in 1846 he drew up a scheme for a school of technology which some years later and with slight modifications he brought to a realization in the Massachusetts institute of technology. Although not a New England man by birth or education, he had occasionally visited Boston and was greatly impressed with it as a suitable locality for such an institution. He left Virginia to reside in Boston in 1853, and here, for a period of nearly ten years he worked, wrote and lectured, keeping all the time in mind the organization and development of the school of technology, the plans of which he had so long and so carefully considered. On April 10, 1861, the act incorporating the Massachusetts institute of technology received the approval of Governor Andrews, just as the nation was plunging into what proved to be a mighty struggle for its existence. A year later Professor Rogers was formally elected president of the institution, which as yet had no material existence. Indeed the war for the preservation of the Union delayed the consummation of his desires until February, 1865, at which time instruction in the new school was actually begun. During these years, as well as during the earlier years of the actual existence of the school, the organization was maintained

and the work carried on under great discouragement, mainly through the personal exertions and influence of Dr. Rogers, its president. He had already attained a high reputation as a scientific man, and to this he added a rare power of lucid explanation and popular exposition of scientific discovery This, with his simple and engaging manner, enabled him to gather about the young and feeble educational experiment a number of men, many of them distinguished in various walks of life, who loyally put themselves under his leadership in all matters relating to the institute. The earliest financial support came from two citizens of Boston, Dr. Walker and Mr. Huntington, who contributed $50,000 towards the erection of a building. When instruction began in 1865 there were enrolled 15 students, but the marvellous material development of the country which followed the civil war was favorable to the growth of the school and its prosperity rapidly increased. In 1870, owing to ill health, Dr. Rogers retired from the presidency and was succeeded by Professor John D. Runkle, who had been professor of mathematics from the beginning. In 1878 Dr. Rogers, having partially recovered his health, was induced to return to the presidency, holding that office until 1881, when, on his recommendation, General Francis A. Walker was elected as his successor. A year later, at noon of May 30th, 1882, Dr. Rogers, in the midst of an address to the graduating class of the institute, in which his hearers were delighted with an apparent revival of the spirit and eloquence with which he was accustomed to enrich every occasion for dignified address, fell upon the platform of Huntington hall, surrounded by the material realization of his dreams of nearly forty years earlier, and by those who, by the closest associations, had learned to love him as few are loved.

Under the able leadership of his distinguished successor, the Massachusetts institute of technology entered upon a new career of growth and development which has placed it in the front rank of its kind throughout the world.

By the act of incorporation of 1861 William Barton

Rogers and his twenty associates were made a body corporate "for the purpose of instituting and maintaining a society of arts, a museum of arts and a school of industrial science." The latter has become the prominent feature of the institute. "It is devoted to the investigation and teaching of science as applied to the various engineering professions, namely, civil, mechanical, mining, electrical, chemical and sanitary engineering, and naval architecture, as well as to architecture, chemistry, metallurgy, biology, physics and geology. A course of a less technical nature, designed as a preparation for business callings, is also provided." There is also affiliated with it the Lowell school of practical design, established in 1872 by the trustee of the Lowell institute for the purpose of promoting industrial art in the United States. The course in this school covers three years of instruction in the art of design including technical manipulations; copying and variation of designs; original designs and the making of working designs.

The institute offers thirteen distinct courses, each of four years' duration, in civil engineering, mechanical engineering, mining engineering and metallurgy, architecture, chemistry, electrical engineering, biology, physics, general studies, chemical engineering, sanitary engineering, geology and naval architecture. It is amply equipped with laboratories, museums and libraries. Its officers of instruction number 136 in all departments. Students in all departments numbered 1171 in 1899, and the number of graduates from the beginning is nearly two thousand.

The institute is supported for the most part by the income from private endowments and from fees received from tuition. It receives, however, one-third of the income of the commonwealth of Massachusetts from the national land grant funds and subsequent national appropriations for land grant colleges. During the past two years it has received from private bequests something over one million dollars. It furnishes free tuition to forty students from the public schools of Massachusetts from which it is reimbursed by

legislative appropriation. Its government is vested in a corporation consisting of not more than fifty members, including the governor of the commonwealth, the chief justice of the supreme judicial court and the secretary of the state board of education. The corporators, excepting the *ex-officiis* members, hold office for life and vacancies are filled by the corporation. It confers the degree of bachelor of science on the completion of any of the regular courses of study and that of master of science for graduate courses of at least one year.

The Worcester polytechnic institute at Worcester, Massachusetts, was incorporated in May, 1865, only a few weeks after the Massachusetts institute of technology received its first class of fifteen students in rented rooms in Boston. In the latter part of 1864 Mr. John Boynton of Templeton, in Worcester county, a merchant who by thrift and economy had accumulated a considerable fortune, made known to Mr. David Whitcomb of Worcester, who had been his partner and was his most trusted friend, his desire to devote the major portion of his savings to the establishment of a school for training young men for industrial pursuits. He was wisely advised by Mr. Whitcomb, a man of rare sagacity, and Rev. Dr. Seth Sweetser, then pastor of the Central church of Worcester, was also consulted. It developed that a distinguished citizen of Worcester, Mr. Ichabod Washburn, the founder of the great Washburn & Moen steel and wire manufactory, long the leading establishment of its kind in the world, had about a year earlier confided to Dr. Sweetser his own desire to contribute towards the establishment of an institution of like nature. A conference, including among others the Hon. Emory Washburn, President Hill of Harvard university, the Hon. George F. Hoar and the Hon. Stephen Salisbury, resulted in a union of the two schemes, Mr. Washburn contributing the cost of the erection, equipment and endowment of extensive workshops, since known as the Washburn shops, to form a part of the means provided for the proper training of mechanical engineers.

Mr. Boynton's gift was $100,000. The citizens of Worcester undertook to provide for the erection of a suitable building upon a beautiful and convenient site given by Stephen Salisbury, who was also one of the most generous contributors to the building fund. It is interesting to note that many of the subscribers gave small sums, tradesmen and others uniting, to the number of about five hundred, to swell the amount. The corporation organized with the Hon. Stephen Salisbury as president, and in 1868 the first building, Boynton hall, was dedicated and the work of the school inaugurated. Its first president was Dr. Charles O. Thompson, a man most admirably fitted for the development of the new and somewhat novel plans of the trustees and donors. Dr. Thompson made a special study of European technical schools, particularly of the Russian schools, the imperial technical school at Moscow and the institute of technology at St. Petersburg.

In these schools the experiment was first made of combining in the engineering courses the study of text-books, lectures and other exercises long known to form a necessary part of scholastic training, with practical exercises in workshops in which the student was made familiar with machines, their construction and use, and the nature of the materials upon which they worked. Dr. Thompson was especially impressed with this plan as representing very closely the ideas of the founders of the Worcester polytechnic institute, and under his able direction it became the central idea about which the organization of the school crystallized. He remained at its head for fourteen years, during which it developed the distinctive qualities by which it has since been characterized. During the thirty years of its existence it has received numerous additions to its original funds, mostly from citizens of Worcester and especially from the Salisburys, including Stephen Salisbury 2d, the first president of the board of trustees, and Stephen Salisbury 3d, the present (1899) head of the corporation. As the school grew, and with it the demands of new methods of instruc-

tion, several large and commodious buildings were added to the original, notably the Salisbury laboratories for physics and chemistry, the gift of the present Stephen Salisbury; the engineering building, with its mechanical laboratories, erected by means of an appropriation by the state of Massachusetts of $100,000; the power laboratory, the hydraulic laboratory, etc. Perhaps the distinctive feature of the school is the large utilization of workshops in connection with instruction in mechanical and electrical engineering. The constructive principle is dominant in the workshop training, and the student during his course, or sometimes in conjunction with a small group of his fellows, actually produces all the parts of a tolerably complex machine, involving the use of a wide variety of machine tools and of materials used in construction. The excellence of his work or design is tested as an actual commercial product, which is held to be the final test, and to secure the best results the Washburn shops maintain a commercial side, the greater part of the output of which consists of special machines, appliances and devices originally designed and developed there, representing the results of actual engineering practice on the part of students and professors.

The institute offers five courses, each of four years duration, namely, mechanical engineering, civil engineering, chemistry (including sanitary and industrial chemistry), electrical engineering and general science. It grants the degree of bachelor of science to those who complete any one of its courses, and the master's degree for graduate study of not less than one year. Professional degrees of mechanical, civil and electrical engineering are granted upon conditions requiring still further work and several years of successful professional experience.

Its corps of instructors numbers 31 and its students (1899) 236. Its graduates number (1899) 823. Its support is derived from the income of its endowment and fees for tuition. It gives free tuition to forty students from the state of Massachusetts for which it is reimbursed by annual

appropriation from the state. It also furnishes free tuition to about thirty young men, residents of Worcester county, for which funds have been provided by donation. Its government is vested in a board of twelve trustees, one being appointed by the state board of education, and the mayor of the city of Worcester being a member *ex-officio*. Other members are chosen by the board and serve for life.

The Lehigh university, at South Bethlehem, Pennsylvania, although by name a university, is and has always been pre-eminently a technical or engineering college of a high grade. The original object of its founder was to afford the young men of the Lehigh valley a complete education, technical, literary and scientific, suitable to fit them for those professions represented in the development of the peculiar resources of the rich mining territory in which it is located.

In 1865 the Hon. Asa Packer signified his intention of providing such an institution by announcing his willingness to donate to it the sum of $500,000 and one hundred and fifteen acres of land in South Bethlehem on which the buildings might be placed. Judge Packer was born in Groton, Connecticut, in 1806, and died in Philadelphia in 1879. After receiving a common school education he began learning the trade of tanning, but gave it up to serve an apprenticeship as a carpenter. He worked at this trade for some time, but while still under twenty years of age, on the opening of the Lehigh Valley canal, he established himself at Mauch Chunk, becoming the owner and master of a canal boat for carrying coal to Philadelphia. Although entirely lacking preliminary training, he possessed the instincts of an engineer, and was soon extensively engaged in the building of locks and boats and in the mining and transportation of coal. He projected the Lehigh Valley railroad, and through his varied and extensive operations in mining and transporting coal became the richest man of his day in the state of Pennsylvania. He filled important political offices, was a member of congress and was the candidate of his party for governor of the state in 1869. He gave to the

newly-established institution more liberally during his life than he had at first announced, and at his death bequeathed to it an endowment of nearly $2,000,000, the total amount of his benefactions reaching over two and a half million dollars.

The institution was incorporated in 1866, and its first class was graduated in 1869. Its first president was Professor Henry Coppee, LL.D. It is well equipped with suitably-appointed laboratories, an astronomical observatory, a museum which is especially rich in minerals, and a large and well-endowed library. While it offers a classical course, its resources are almost exclusively devoted to the school of technology. In this six courses are offered as follows: Civil engineering, mechanical engineering, metallurgy, mining, electrical engineering and chemistry. Its corps of instructors numbers 41 and its students (1899) 325, of whom all except ten were in the technical or scientific courses. Up to 1899 its graduates numbered nearly one thousand.

The Lehigh university is supported by the income from its endowments and the fees charged for tuition, although it has received occasional appropriations from the state. It is governed by a board of ten trustees, together with nine honorary trustees, four of whom are chosen from the alumni to serve for a fixed term of years.

The Stevens institute of technology, at Hoboken, New Jersey, was opened for the admission of students in September, 1871. Mr. Edwin A. Stevens, its founder, was a member of a distinguished family of engineers. His grandfather, John Stevens, had been a member of the continental congress, and his father, also John, had filled offices of trust and responsibility during the revolutionary war, besides being the most famous engineer of his time. At the close of the war for independence he was a man of independent wealth, owning the island of Hoboken on which he lived during the summer, and he devoted practically the remainder of his life to experimental engineering at his own cost for the common good. Through his influence the American patent law was

enacted. · He was one of the earliest users of steam and he made important improvements in the method of generating it. He was the first to navigate the Hudson by means of a steamboat, which he did successfully in 1804, and by a vessel propelled by twin screws, essentially the same in form as those now universally in use, and he was always a warm advocate of the screw propeller. He established the first steam ferry in the world, was the first to navigate the ocean by steam and in 1812 he made the first experiments in the use of artillery against iron armor, and about the same time he strongly urged the construction of a railroad between the seaboard and the great lakes instead of a canal which was then being talked of. His suggestions were rejected by the commissioners, who considered them impracticable and visionary.

His sons, Robert L. and Edwin A., inherited the engineering tastes of their father and added new lustre to the fame of the family by remarkable achievements in the field of railroad development and marine engineering. The earliest railroads of importance in the United States were built under their direction and the two brothers were the joint inventors of many improvements in track, rolling stock, power, etc. Both were greatly interested in the application of engineering to warfare and especially in improving naval attack and defense, and Robert L. Stevens built the first ironclad vessel ever constructed. In the will of Edwin A. Stevens, dated April 15th, 1867, he bequeathed a block of ground in the city of Hoboken, with $150,000, for the erection of buildings thereon "suitable for the uses of an institution of learning, and also $500,000 as an endowment fund for the support of the same. In 1870 Professor Henry Morton, Ph. D., at that time professor of chemistry in the University of Pennsylvania and also secretary of the Franklin institute, was selected as the president of the new institution for which a charter had been obtained in February of the same year. Dr. Morton, to whom the success and high character of the school is largely due, has contin-

ued to serve as its president from the beginning. In 1875 a mechanical laboratory was established under the direction of Professor R. H. Thurston, who was the first professor of mechanical engineering in the institute. The Stevens institute is essentially a school of mechanical engineering alone, and it offers but one course of study, which requires four years for its completion. Much attention is given to practical laboratory and workshop methods. There is a department of tests in which are undertaken measurements of the performance of steam engines and other motors, of the efficiency of boilers, electrical and hydraulic apparatus, of the strength of materials and kindred problems. Its officers of instruction are 21 in number and its students (1899) 214. Since its organization the institute had graduated about 700 students. It grants the degree of mechanical engineer to those who have completed its course of study and it has bestowed honorary degrees of doctor of philosophy and doctor of engineering. Since the original bequest of Mr. Stevens it has received considerable additions to its endowment fund, and its president, Dr. Morton, has been among the liberal donors. It derives its support from the income from its invested funds and from its tuition fees. Its government is in the hands of a board of twelve trustees, one of the number being an alumnus.

The Case school of applied science, at Cleveland, Ohio, was incorporated on March 29th, 1880. Leonard Case, its founder, was born in Cleveland on June 27th, 1820. His father, also Leonard Case, had come to Ohio from Pennsylvania at the beginning of the century. By judicious purchases of public lands in and near Cleveland, then a village, now (1899) a flourishing city of over 300,000 inhabitants, and by active participation in early railroad enterprises, he accumulated a large estate, all of which his son, Leonard, inherited. The latter was educated at Yale college, being a member of the class which was graduated in 1842. He was, as a young man, inclined rather to literary and scientific pursuits than to business. He was especially fond of

scientific and mathematical studies, but he possessed considerable real literary ability, as was evidenced by occasional poems and translations, some of which were published in the best magazines of the day. In 1876 he had already determined upon founding a school of science, and in 1877 he executed a deed of trust setting apart certain real estate for the support of the institution, to take effect upon his death, which occurred on January 6th, 1880.

In this he directed the trustees "to cause to be formed and to be regularly incorporated under the laws of Ohio an institution of learning to be called 'Case school of applied science,' and located in said city of Cleveland, in which shall be taught by competent professors and teachers mathematics, physics, engineering — mechanical and civil — chemistry, economic geology, mining and metallurgy, natural history, drawing and modern languages, and such other kindred branches of learning as the trustees of said institution may deem desirable." Instruction began in 1881, with a class of 16 students, the school being carried on from that time until the summer of 1885 in the old Case homestead. A commodious building having been erected for the use of the school, it was occupied at the beginning of the term in September, 1885. A year later the building with all that it contained was destroyed by fire. It was promptly rebuilt and occupied in 1888. Since that time several additional buildings for laboratory and shop exercises have been erected.

The Case school of applied science offers eight regular courses of instruction, each requiring four years. They are civil engineering, mechanical engineering, electrical engineering, mining engineering, physics, chemistry, architecture and general science. In 1899 there were 21 instructors and 218 students. From the beginning it has graduated about 230 men. The degree of bachelor of science is granted to all who complete one of the regular courses. That of master of science may be conferred upon graduates who have devoted at least one year exclusively to graduate study.

Professional degrees, namely, civil engineer, mechanical engineer, electrical engineer and engineer of mines may also be conferred after one year of graduate study or after professional work in positions of responsibility, for three years after graduation. The property left by Mr. Case as an endowment for the support of the school is valued at about $2,000,000, and the amount invested in buildings and equipment is about $350,000. The school derives its support from the income from its endowment and tuition fees. Its government rests with a corporation consisting of twenty men, from whom six known as trustees are selected.

The Rose polytechnic institute, at Terre Haute, Indiana, was organized as early as 1874, but it was not open to students until 1883. The intervening years were spent in the erection of buildings for the accommodation of the school and in the personal examination by members of the board of managers of the leading schools of science and technology in the country. Its founder was Chauncy Rose, born in Wethersfield, Connecticut, in 1794, died in Terre Haute in 1877, having settled in Indiana in 1817. Mr. Rose was a successful business man, made judicious investments in real estate and was active in the early railroad development of Indiana. Throughout his long life he was distinguished for the sturdiest integrity in all business matters and for his generous and philanthropic disposition. An incident of the latter part of his life forcibly illustrates those qualities which made him the founder of schools, orphan asylums, free dispensaries, etc. His brother John lived in New York city and had also become a man of great wealth, concerning the disposition of which, after his death, he had very clear and well-defined ideas. Through a serious error in the preparation of his will, it appeared that if executed under the laws of New York it would fail in accomplishing the evident desires of the testator. Chauncy Rose at once instituted legal proceedings to have the will set aside, in which he succeeded after six years of litigation. He was himself the sole heir, and the estate of over $1,500,000

became his, but he immediately expended the whole in the exact manner desired by his brother, mostly in various charities in New York city.

He carefully attended to the erection of the buildings for the school he was to found, and on his death left an endowment for it of over half a million dollars. The trustees, in their examination of various other institutions, were much impressed with the organization and character of the Worcester polytechnic institute, and accordingly they invited Dr. Charles O. Thompson, its president, to come to Terre Haute as the first president of the Rose polytechnic. He accepted the invitation, and, after nearly a year in Europe, engaged in a renewal of his acquaintance with the leading schools of science and technology to be found there, he began the work of organizing the new institution which was opened to students in 1883. Dr. Thompson's work at the Rose polytechnic was unhappily cut short by his death only a little more than a year after the opening of the institute, but in that time its organization was practically completed, following closely the lines which he had previously established at Worcester, to which full reference has already been made.

The Rose polytechnic institute offers four separate courses of study each of four years' duration. They are in mechanical engineering, electrical engineering, civil engineering and architecture, and in chemistry. Its faculty of instruction (1899) included 15, and its students numbered 100. The total number of its graduates is about 260. It confers the degree of bachelor of science upon those who have completed any of its courses. That of master of science is conferred two years after graduation, at least one of which must be spent in graduate study, approved by the faculty. Professional degrees, mechanical engineer, electrical engineer or civil engineer will be conferred upon those who have already received their master's degree and who have subsequently spent at least two years in the successful practice of their profession. The institute derives its sup-

port from its endowment funds and tuition fees. Additions to the endowment fund have been received since the death of the founder. It is governed by a board of managers consisting of nine men, with power to fill vacancies. By arrangement one member of the board is an alumnus, elected by the alumni, to serve for one year.

The Polytechnic institute of Brooklyn, at Brooklyn, New York, was originally an academy or preparatory school of high grade, existing since 1854 under the name "Brooklyn collegiate and polytechnic institute." Two courses of advanced study were provided in 1870, and in 1889 it was reorganized and rechartered under the name it now bears. One of its courses of study is called the "liberal" course and leads to the degree of bachelor of arts, but the principal work of the institute is in applied science. Here three courses are provided, engineering, chemical and electrical. Those who complete these courses, which are each four years in length, receive the degree of bachelor of science. Post graduate courses are provided. In 1899 the corps of instructors numbered 11, and there were 79 students. In its technical and engineering courses it has graduated nearly a hundred men. Its income is derived from endowment funds and tuition fees.

The Armour institute of technology, at Chicago, Illinois, was founded by Philip D. Armour in 1892, and originally chartered as "the Armour institute." Mr. Armour was born in Stockbridge, N. Y., in 1832. He received only a common school training, and after spending some time as a miner in California, he engaged in a commission business in Milwaukee. In 1863 he began his career as a grain and pork merchant, and since 1875 he has been at the head of the firm of Armour & Company of Chicago, the largest dealers in dressed meats and provisions in the world. He has given generously towards the establishment and maintenance of a mission in Chicago known as the Armour mission. His gifts to the institute of technology which bears his name already amount to more than $2,500,000. In the first public

announcement of his gift he said: "This institution is founded for the purpose of giving to young men and women an opportunity to secure a liberal education. . . . It is not intended for the poor or the rich, as sections of society, but for any and all who are earnestly seeking practical education. . . . The institute is not a free school, but its charges for instruction are in harmony with the spirit which animates alike the founder, the trustees and the faculty, namely, the desire to help those who wish to help themselves." Instruction began in 1893, and in 1895 it was somewhat reorganized, full four years' courses were arranged for, and the name changed to the "Armour institute of technology." The principal feature of the school is what is known as "the technical college," to which are allied, under the general organization, the department of domestic arts, the kindergarten normal department, the department of music and the department of shorthand and typewriting. In the technical college five courses of study are offered, a course in mechanical engineering, in electrical engineering, in architecture, in science and in civil engineering. In 1899 the corps of instructors numbered 31. No information concerning the number of students is given in the published yearbook. Its graduates probably number about 60. It confers the degree of bachelor of science. It is especially well equipped in apparatus relating to electric measurements. Its government is vested in a board of six trustees of which the founder is one, as is also the president of the institute.

The limits to which this monograph is restricted will not permit detailed reference to a greater number of institutions belonging to the group of independently organized and endowed schools of technology, although there are several others that, by reason of their excellent facilities and comprehensive courses of study, are quite as important as some of the above which have been selected as types. Within two or three years additions to the list have been made, among which may be mentioned the Bradley polytechnic institute at Peoria, Illinois, and the Clarkson institute of

technology at Potsdam, N. Y. There are a number of excellent schools in the southern states, mostly supported, however, by state appropriations.

Several of the most important schools of science and engineering in the United States belong to the second group, being affiliated with universities and colleges and sharing with other departments the income from private endowments, facilities and faculties of instruction. Less detailed consideration will be given them here on that account, as they will doubtless receive a large measure of attention in monographs relating to these institutions. This exposition would be quite incomplete, however, without reference to them, and, at the risk of duplication, a brief description of some of the leading examples will be given.

The Sheffield scientific school of Yale university, at New Haven, Connecticut, was organized in 1847 as a school of applied chemistry. In 1860 it received its first considerable endowment from Joseph E. Sheffield of New Haven. Mr. Sheffield was a native of Connecticut, born in 1793. After receiving a common school education he began, at the early age of fifteen years, a long and successful business career. For more than a quarter of a century he lived in the south, becoming the chief cotton merchant in Mobile, Alabama, but in 1835 he returned to his native state and established himself in New Haven. He was active in canal and railroad development, both in New England and the west, accumulating a large fortune from which he made munificent donations to Yale college. In 1860 he provided suitable buildings for the scientific department and made liberal endowments for its support. The Sheffield scientific school is devoted to "instruction and researches in the mathematical, physical and natural sciences, with reference to the promotion and diffusion of science, and also to the preparation of young men for such pursuits as require special proficiency in those departments of learning." Instruction is specially planned for two classes of students: 1st, graduates of Yale and other universities or colleges, and others specially quali-

fied for advanced or special scientific study; 2nd, undergraduates who desire a training chiefly mathematical and scientific to fit them for higher scientific studies or for such occupations as demand such training. The undergraduate courses extend through three years, but the requirements for admission are considerably in advance of those in institutions whose courses are of four years. A number of courses of study are provided, at least ten being distinctly separate. They include chemistry, civil engineering, mechanical engineering, electrical engineering, agriculture, natural history, mineralogy, biology, mining and metallurgy. There are also a number of graduate courses. The degree of bachelor of philosophy is conferred upon those completing any of the three years' courses of study. The degree of master of science is conferred upon those who have taken their first degree in science and who have had at least one year of resident graduate study, under the direction of the governing board. Two additional years are required for the degree of civil engineer, or mechanical engineer and the degree of doctor of philosophy is also conferred. In 1899 there were 59 graduate students, 13 special students and a total of 597. The total number of professors and instructors is 63. The faculty is distinct from that of the academic department of Yale college, but some of the instructors are connected with other departments. The governing board consists of the president of the university with the director of the scientific school and members of the faculty permanently attached to the school. Degrees are conferred by the president of the university on the regular university commencement day and the corporate control of the school is that of Yale university.

The Lawrence scientific school of Harvard university, Cambridge, Massachusetts, was founded by Abbott Lawrence in 1847. He was the younger of two brothers, born in Groton, Massachusetts, late in the last century, who were the most famous merchants in Boston during the first half of this. He was a graduate of Harvard college and was distin-

guished not only for great success in mercantile and manufacturing operations, but also for the important public services with which he was occupied during the later years of his life. He was a member of congress, a commissioner for negotiating the northeast boundary treaty with Great Britain, and served as minister to England from 1849 to 1852. His first gift for the endowment of the school which bears his name was $50,000, to which large additions were afterwards made by himself and members of his family. The primary object of the institution was to afford an opportunity for special study and training in science which the then existing foundations and departments of the university did not offer. Not the least of the important benefits it conferred during the earlier years of its existence was the bringing of Professor Louis Agassiz into close relations with the university, a special chair of zoology and geology in the scientific school having been created for him by Mr. Lawrence in 1848. It was originally intended that the Lawrence scientific school should be independent of Harvard college, and for many years it was so maintained, but in recent years it has gradually become merged with it until it now forms a part of the university, its government together with that of the college and the graduate school being under the faculty of arts and sciences. It confers or rather prepares for the degree of bachelor of science by four years' courses, eleven in number, including civil engineering, electrical engineering, mechanical engineering, mining and metallurgy, architecture, chemistry, geology, biology, general science, science for teachers, and anatomy and physiology. These courses are essentially required, while those of the college are largely elective. The particular object of the school is to afford to men of sound preliminary training a liberalized education in various branches of science. So far as possible the instruction relates rather to the principles of science than to technical work, the intention being to make the graduates ready for the apprenticeship of their professions. It avails itself of the great resources of Harvard

university, its museums, libraries, laboratories, etc., these being used in common by students who are candidates for the degrees of bachelor of science, bachelor of arts, or for the several graduate degrees conferred by the faculty of arts and sciences. While there are certain professors whose duties are confined to the scientific school, a great part of the instruction is in common with the college. It is so closely linked with Harvard college that no clear discrimination can be made in the funds which support the scientific school and other foundations. There is considerable election in the subjects required for admission and their range is essentially the same as with the college. In 1899 there were 425 students in the scientific school.

The Chandler school of science of Dartmouth college, Hanover, New Hampshire, was established in 1851 by the trustees of Dartmouth college, on the receipt of a bequest of $50,000, from Abiel Chandler, who left it to them in trust "for the establishment and support of a permanent department or school of instruction in the college, in the practical and useful arts of life." Mr. Chandler was born in Concord, New Hampshire, in 1777. Until he was twenty-one years of age he worked upon a farm but soon after he entered Harvard college from which he was graduated in 1806. For several years he was a teacher but afterwards engaged in business in Boston, retiring with a fortune in 1845. In addition to his bequest to Dartmouth college he distributed most of his estate in charity. The Chandler school was maintained as a separate department of the college for many years but it has recently been formally incorporated into the college and it is now known as the Chandler scientific course leading to the degree of bachelor of science. This course covers four years and is best described as a course in general science, including modern languages, mathematics, history, political science, etc., along with a good representation of the exact and natural history sciences. About 150 students are in the Chandler course.

Affiliated with Dartmouth college is the very important

graduate school of civil engineering known as **The Thayer school of civil engineering.** It was founded in 1867 by Gen. Sylvanus Thayer, U. S. A., who gave a fund of $70,000. General Thayer was born in Massachusetts in 1785. He was graduated from Dartmouth college in 1807 and from the U. S. military academy at West Point, which was then in a very elemental stage, in 1808. He became one of the most distinguished engineers of the army, was sent to Europe to study military works and schools, and on his return in 1817 was made superintendent of the U. S. military academy at West Point, a position which he held for sixteen years. During this time he entirely reorganized the school, putting it upon the same plane as the best military schools of Europe. So important were his services to the academy that his monument at West Point bears the inscription "Colonel Thayer, father of the United States military academy." It was his desire to found at Dartmouth college a graduate school of engineering, exacting in its requirements and complete and thorough in its work. Being a graduate school, its course, which occupies two years, is essentially professional. It devotes itself exclusively to civil engineering in the broader sense, and the high standard of admission has necessarily restricted the number of students. The first class was admitted in 1871, and from that year to 1897, inclusive, 123 have entered, at an average age exceeding 23 years. Of these 79 were graduated with the degree of civil engineer. The government of the school is vested in a board of overseers consisting of the president of Dartmouth college, with four officers of the engineer corps of the United States army, active or retired.

The School of mines of Columbia college, now Columbia university, New York city, began its work in 1864. Its establishment was due, primarily, to Professor Thomas Egleston. Professor Egleston was graduated at Yale in 1854, and at the *École des mines* in Paris in 1860. In 1863 he prepared and published a plan for a school of mines which was the basis of the organization at Columbia college.

Up to that time the enormous mineral resources of the United States were almost unknown; at least there had been little systematic effort towards their development. Such mining as was carried on was mostly under the direction of so-called "practical" miners, whose methods were wasteful and extravagant. A few experts had come from European schools, but the full exploitation of the rich deposits which the country possessed demanded a large number of trained and educated men. This demand the School of mines was destined to supply in a large measure, and it is difficult to overestimate the importance of its work during the quarter of a century following its foundation. The trustees of Columbia college permitted the use of certain rooms in the college buildings for the school and such collections of minerals, etc., as it might obtain. Professor Egleston was made professor of mineralogy and metallurgy, without salary, and he was shortly after joined by Professors Charles F. Chandler and F. L. Vinton on the same conditions, the faculty being expected to depend upon fees for support. The School of mines opened on November 15th, 1864, with 29 students, and its success was a gratifying surprise from the very beginning. The students were generally of somewhat mature age, and many of them were college graduates. Although the college had in no way committed itself to the financial support of the school, small sums of money were granted, and the importance of the school to Columbia college became more and more evident. Early in 1865 the School of mines was formally adopted as a co-ordinate branch of the college, and it is not too much to say that for many years the college was most widely known by reason of this connection. The primary object of the school was the education and training of *mining* engineers and metallurgists. It gathered together a faculty of men distinguished in their specialties, and it was soon evident that it could wisely extend its operations so as to cover other branches of engineering and applied science. Courses of study in civil engineering, applied chemistry, sanitary

engineering, geology and architecture were added, although it still continued under the original name, School of mines. In 1889 a course in electrical engineering was added, and later on in mechanical engineering. In 1896 the title "Columbia university" was adopted as covering all the departments of instruction and research previously associated with or forming a part of Columbia college, and the title "School of mines" is now restricted to its original significance. The various engineering and science courses are now collectively directed by the "faculty of applied science," under which are the four schools of mines, chemistry, engineering and architecture. There is also a school of pure science under the direction of a faculty of pure science.

The School of engineering offers courses in civil, electrical and mechanical engineering, all of four years' duration, and corresponding degrees are granted. All of these schools are extensively equipped, and much attention is given to graduate courses and work.

In the School of pure science instruction is given in anatomy, astronomy, bacteriology, botany, chemistry, geology, mathematics, mechanics, mineralogy, physics, physiology, and zoology. The faculty of pure science exercises special supervision over the instruction and work of all candidates for the degrees of master of arts and doctor of philosophy in pure science. The several faculties of instruction in the university are not entirely distinct, but the total number of those giving instruction, in one way or another, in the courses in pure and applied science, is probably not far from 100, including professors, adjunct and associate professors, instructors, tutors and assistants. In 1899 there were registered 470 students under the faculty of applied sciences. The registration in the School of pure science was approximately 100. On January 1st, 1899, the total number of graduates in science was 1172.

Practically all colleges or universities in the United States offer courses in pure or applied science, and while their work may not be differentiated from that of the departments suf-

ficiently to constitute a distinct school, it is often of high quality and the material appliances and equipment, everything that could be desired. Of the older of those giving special attention to science and engineering a few will be briefly mentioned. They will doubtless receive full consideration under another division of the educational institutions of the United States.

The College of the university of Pennsylvania provides, under a foundation known as the Towne scientific school, courses in architecture, mechanical and electrical engineering, chemistry and chemical engineering. They are of four years' duration and lead to the degree of bachelor of science. Ample facilities in the way of laboratories, machinery and apparatus, libaries, etc., are provided. Besides these courses in engineering, there is a course in biology, and all departments are represented in the university curricula and faculty of instruction. The University of Pennsylvania was among the earliest in its class to undertake systematic instruction in science, technology and engineering. In 1852 it was resolved to establish a department of mines, arts and manufactures, and professorships in geology and minerology, and civil engineering and mining, and two regular courses in science were offered. In 1874 John Henry Towne, a trustee of the university, made the university the residuary legatee of his large estate. Whatever sum might accrue from this bequest was to form a portion of the endowment fund of the university, and the income from it was to be devoted exclusively to the payment of the salaries of professors and instructors in the department of science. In recognition of this generosity the department was named "the Towne scientific school of the University of Pennsylvania."

The John C. Green school of science is one of the departments of Princeton university. Mr. Green was a wealthy merchant in New York city, who devoted much of his large fortune to charitable and educational foundations. He contributed generously to Princeton university aside from his

gift of $50,000 to found the school of science in 1873. This amount was subsequently much increased by the residuary legatees of his estate. Instruction is given in general science, civil engineering and electrical engineering. The courses are four years in length and lead to the degree of bachelor of science. In 1899 the number of students in the science department of the university was 338.

Union college, at Schenectady, New York, founded in 1795, was one of the earliest institutions to furnish instruction in engineering and general science. It was among the first to recognize the importance of modern languages, and at an early date it added a "scientific course" to the time-honored curriculum, which included little besides Latin, Greek and mathematics. In 1845 it offered courses in civil engineering, and there has been added recently a department of electrical engineering which will enjoy exceptional opportunities, owing to the fact that the great manufacturing plant of the General electric company is located at Schenectady.

Washington university, at St. Louis, Missouri, has long maintained a school or department of engineering of excellent reputation. It offers five courses of study, namely, in civil engineering, mechanical engineering, electrical engineering, chemistry, and science and literature. They are of four years' duration and lead to the degree of bachelor of science. Advanced and professional degrees are conferred on about the usual conditions as to study and experience. The testing laboratory of the department of civil engineering is one of the best known, especially for the large amount of timber testing for the U. S. government which has been done in it. The total number of graduates of the School of engineering, up to 1899, was 186.

The University of Cincinnati, at Cincinnati, Ohio, founded in 1872 upon a bequest of Charles McMicken, a wealthy merchant of Cincinnati, provides courses in general science and in civil engineering. Instruction is also given in applied electricity, but no distinctive course in electrical engineering

is offered. The courses are of four years' duration and lead to the degree of bachelor of science. There is also a course in astronomy, instruction in which is facilitated by an excellent astronomical observatory well equipped with modern instruments and appliances. A course in mathematics, announced in 1890, leads to the bachelor of science degree. In addition to the income from the McMicken fund, the university receives annually a considerable sum collected as a tax upon the taxable property of the city of Cincinnati.

The University of California, at Berkeley, California, includes in its departments a college of agriculture, of mechanics, of civil engineering and of chemistry. A course in electrical engineering is offered in the College of mechanics. They are all of four years' duration and lead to the degree of bachelor of science. There is also an astronomical department in which is included the celebrated Lick observatory at Mt. Hamilton.

There is also in California the well-known **Leland Stanford, Junior, university,** which offers courses in the natural sciences and in civil, mechanical and electrical engineering.

The College of technology of Tulane university of Louisiana at New Orleans, Louisiana, is an important school not only on account of the excellence of its courses and facilities for instruction, but specially by reason of its location, and it is destined to be an important factor in the development of the great resources of the southern part of the United States. It offers five courses, namely, mechanical engineering, which includes electrical engineering, chemical engineering, sugar engineering, civil engineering and architecture. The course in "sugar engineering" is unique, and of special value to the sugar producing interests of the region in which the college is located. It includes not only the chemistry and physics of sugar preparation and cultivation, but the mechanics and engineering of all machinery and appliances used in a modern sugar-making plant. The degree of bachelor of engineering is conferred upon all who complete one of the courses of the college of technology.

Vanderbilt university, at Nashville, Tenn., maintains a well-equipped engineering department. In 1888 Mr. Cornelius Vanderbilt, the grandson of the founder, made a donation to the university of $30,000 for the erection of a building for mechanical engineering. Previous to that time, and in fact, from the opening of the institution in 1876, courses of science and civil engineering had been provided and in 1899 mechanical and mining engineering were added. In 1895 a course in electrical engineering was established. Four years are required to complete any of the courses and the degree of bachelor of engineering is conferred upon those who successfully accomplish the work in either course. In 1899 there were 18 students in the engineering department.

There remains to be considered the third group of schools of science and engineering, which includes those depending for support largely upon state or national appropriations, or related to the universities or colleges deriving a large part or all of their income from these sources.

Among the best known schools of engineering in the country are those forming a part of Cornell university, Ithaca, N. Y. Those branches of engineering which depend principally upon mechanics are represented in Sibley college, while civil and hydraulic engineering, geodesy and kindred branches are included in the "college of civil engineering."

The Sibley college of mechanical engineering and the mechanic arts was established through the generosity of Hiram Sibley who had been interested with Mr. Cornell in the great telegraph enterprises out of which grew the Western Union telegraph company. He was born in Masachusetts in 1807 and died in Rochester, N. Y., in 1888. His interest in the telegraph began with the early experiments of Morse, and he was actively engaged in the attempt to connect Europe and America telegraphically by way of Bering Straits. He was also interested in railroad enterprises and in farming on a large scale, being at one time the largest owner of improved lands in the United States. The college of mechanical engineering was begun by a gift from

Mr. Sibley sufficient for the erection of a building and for the support of a chair of "practical mechanics and machine construction." He continued making additions to his first donations, and in 1885 the trustees of the university organized the college under the name by which it is now known. Mr. Sibley's gifts amounted to $180,000, and $50,000 additional have been contributed by other members of the family. The Sibley college includes eight departments; mechanical engineering, experimental engineering, electrical engineering, machine design, mechanic arts or shop work, industrial drawing and art, and graduate schools of marine engineering and naval architecture, and of railway mechanical engineering. Courses of study are four years in length and the degree of mechanical engineer, electrical engineer, etc., are conferred upon those who successfully complete the respective courses. In 1899 the number of students in Sibley college was 492. The laboratories, museums, shops and other parts of the college are very completely furnished and equipped.

The College of civil engineering provides instruction in all departments of that subject and particularly in some of the more advanced developments of the science. Special instruction is given in bridge engineering, railroad engineering, sanitary, municipal, hydraulic and geodetic engineering. Numerous graduate courses are provided, for illustrating which an astronomical observatory or laboratory, a magnetic laboratory, an extensive hydraulic laboratory and other laboratories furnish ample means. The museums of the College of civil engineering are rich in collections of models, instruments of precision, base line and gravity apparatus, together with a large assortment of the usual field instruments, such as transits, theodolites, levels, etc. In 1899 there were registered 186 students in this college.

The University of Michigan, at Ann Arbor, Michigan, was organized by legislative act in 1837, which made provision for instruction in engineering. Regular instruction was not begun, however, until 1853, and the first degrees

were conferred in 1860. The engineering courses were included in the department of literature, science and the arts until 1895, at which time the department of engineering was established. Courses are offered in civil, mechanical, electrical and chemical engineering, and four years are usually required to complete any one of these. All lead to the degree of bachelor of science. Advanced degrees are conferred for graduate courses of study. In 1899 there were registered 218 students in the department of engineering.

Purdue university, at Lafayette, Indiana, is in reality the Indiana institute of technology. It was originally organized under the Morrill act, but assumed the name which it now bears in 1869 when, by legislative enactment, the state accepted a gift of $150,000 and one hundred acres of land from John Purdue. It receives support from the state and national government, tuition being free to all residents of Indiana. The university embraces six special schools. They are as follows: A School of mechanical engineering, of civil engineering, of electrical engineering, of agriculture, of science and of pharmacy. Courses of study in these schools are four years in length, except in the School of pharmacy, in which the course is completed in two annual sessions of thirty-seven weeks each. The degree of bachelor of science is conferred upon those completing one of the four-year courses, and that of graduate in pharmacy (Ph. G.) upon those who complete the course in pharmacy. There is an exceptionally large and well-arranged engineering building which accommodates the departments of civil and mechanical engineering, and the equipment of the School of mechanical engineering is excellent. It is provided with a locomotive testing plant and other appliances for railway mechanical engineering. The biological, chemical and other laboratories are well furnished. In 1899 the total enrollment of students was 730, including 130 in the School of pharmacy and in a special class in agriculture, and the total number of instructors was about 65.

The University of Wisconsin, at Madison, Wisconsin, was

established by act of the legislature in 1838, but no action was taken under the act except the selection of two townships of land as allowed by congress, for the future support of the institution. The first meeting of the board of regents for the purpose of organizing the university was held in 1849, and the first building was erected in 1851. In 1866 the university was reorganized to secure the land grant under the Morrill act, and in the following year the state began to support the institution by annual appropriations. The College of engineering was opened in 1870, and has established and maintained a high reputation for the excellence of its work. The College of "mechanics and engineering," as it is now called, provides courses of four years' duration in civil, sanitary, mechanical and electrical engineering, and in applied electro-chemistry. These courses all lead to the degree of bachelor of science. Advanced and professional degrees are conferred under certain conditions as to graduate study and experience. An excellent astronomical observatory is available for the instruction of students in civil engineering, and the college is well furnished with laboratories, apparatus, museums, etc. In 1899 there were 242 students registered in the College of mechanics and engineering.

The University of Illinois, at Urbana, Illinois, was founded in acceptance of the national land grant under the Morrill act in 1862, and named at first the Illinois industrial university. Power to confer degrees was granted by the state legislature in 1877, and in 1885 the name of the institution was changed to that which it now bears. The organization includes four "colleges" and six "schools." The colleges are of literature and arts, of engineering, of science and of agriculture. The College of science offers courses arranged in four groups, including the chemical and physical group, the mathematical group, the natural science group and the philosophical group. The College of engineering offers courses in architecture, architectural engineering, civil engineering, electrical engineering, mechanical engineering and

municipal and sanitary engineering. There are also graduate courses in science and in engineering. The degree of bachelor of science is conferred upon those completing one of the courses of four years in the College of engineering, and also in the College of science.

Similar in origin, and in many respects similar in organization, is the **Ohio state university,** at Columbus, Ohio. The institution opened its doors to students in September, 1873. From the beginning instruction in science and engineering has been the most prominent feature of its work. As now organized, the university embraces six colleges, the College of engineering being one. In this college are offered courses in civil engineering, mine engineering, mechanical engineering, electrical engineering, ceramics, industrial arts, chemistry and architecture. There is also a short course in mining, in clay working and in industrial arts. To those who complete these courses, which are of four years' duration (except as explained above), degrees of civil engineer, engineer of mines, mechanical engineer, etc., etc., are granted, and in chemistry and some other courses the degree is bachelor of science. The College of arts, philosophy and science offers a course in general science, leading to the degree of bachelor of science. The university is especially well equipped in its laboratories and museums of geology, agriculture, mechanics and metallurgy. In 1898 there were registered 302 students in the College of engineering.

The University of Minnesota, at Minneapolis, Minnesota, is another example of an important and extensive development upon the land grant foundation. Originally organized in 1851, it dates its real beginning from 1868, when by act of the legislature it was reorganized as the recipient of the Morrill act endowments. Its organization includes a School of technical and applied chemistry, the College of engineering and mechanical arts and the School of mines. The course in the School of chemistry is of four years' duration and leads to the degree of bachelor of science.

The College of engineering and mechanic arts offers courses of four years each in civil, mechanical and electrical engineering, for which the degrees C. E., M. E. and E. E. are conferred. There is also a four years' course in drawing and industrial art for which no degree is granted. In the School of mines there are two regular courses of study, in mining and in metallugy, leading to the degree of engineer of mines (E. M.) and metallurgical engineer (Met. E.) respectively. In 1898 there were registered in the College of engineering 129 students, in the School of mines 54, and in the School of chemistry 6.

The University of Tennessee, at Knoxville, Tenn., chartered in 1794 as "Blount college," becoming in 1807 "East Tennessee college," in 1840 "East Tennessee university," and finally receiving in 1869 the national land grant endowment, was given the name which it now bears by act of the legislature in 1879. In its College of agriculture, mechanic arts and sciences it provides courses in civil, mechanical and electrical engineering, in chemistry and in general science. Its buildings, laboratories, apparatus and general facilities are well up to the requirements of a high standard of work.

The State college of Pennsylvania, at State College, Pennsylvania, is another institution of pronounced success and high character which owes its origin to the Morrill act of 1862 and in which ample provision is made for instruction in pure and applied science in courses and under conditions not varying greatly from those already set forth in describing other institutions of the same type.

Indeed, the list might easily be extended until it included the entire list of state institutions founded under this act or made the recipient of the income which it provides.

If space permitted it would be profitable to consider in some detail two or three special schools, such as the **Michigan School of mines,** the **Colorado School of mines,** institutions which have grown out of the demands of their respective localities, very much as did the famous school at Freiberg long ago. Much might well be said, also, concerning

the efforts made in the United States to establish trade schools, and of their great success in New York, in Philadelphia, and under the direction of the Pratt institute in Brooklyn, and in Cincinnati, and elsewhere, notwithstanding the occasional opposition of trades' unions and other unfriendly organizations.

It is greatly regretted that limitations of space make it impossible to give something of a detailed exposition of the organization and methods of work in a few institutions like the Pratt institute at Brooklyn, the Drexel institute in Philadelphia, each of which is unique, and all of which are doing a most important work.

It will be noted that the leading institutions or departments of institutions in which special attention is given to pure and applied science do not differ materially in their organization, courses of study or degrees conferred. Practically all courses are four years in length, in nearly all the first two years are largely preparatory to the special or professional work of the last two, embracing modern languages, mathematics and a few other subjects, most of which are common to all courses offered. The differentiation begins generally at the opening of the junior or third year, although in some cases it must commence earlier. In the matter of degrees the great majority of schools confer only the degree of bachelor of science at the end of the four years' course, but there are a few that offer the so-called professional degrees such as C. E., M. E., etc., for the mastery of a four years' course. The requirements for graduate degrees are tolerably uniform, being usually a year of resident study with the preparation of a thesis for the master's degree, and in addition to this usually three years' successful professional work with an acceptable thesis for a professional degree.

The requirements for admission are by no means uniform, nor are they extremely varied. Perhaps the typical *average* requirements for admission to schools of science or engineering colleges would include — besides the "common

English branches"—algebra, plane geometry, English literature, history of the United States and either the French or German language. About two to three years' study of the latter would be required, and to this list will often be added solid geometry, plane trigonometry, the elements of physics or chemistry, and sometimes a year or two of Latin. There seems to be a growing tendency towards the introduction of a large number of electives among the subjects required for admission.

It is hoped that a sufficient number of institutions have been considered and that enough has been said of them to exhibit in some degree the enormous educational advance which has taken place during the past fifteen or twenty years throughout the whole country, and especially in what is known as the "middle west." At no previous period in the history of the world has there been so rapid and productive an evolution of educational forces as this period has witnessed, and it will not escape notice that it has largely been a development of methods and appliances for the *study of science, pure and applied.* No sketch of the origin, growth and present condition of the schools of science and engineering in the United States would be complete without reference to **the Johns Hopkins university,** an institution which, although giving little attention to applied science and technology, has been a very large factor in determining the character and methods of instruction to which these schools owe their success. Although not yet twenty-five years old, it is impossible to overestimate its influence upon higher education in this country, and especially is this true in all things relating to science. There is scarcely a college faculty that has not been enriched by the presence of one or more of its graduates, bringing with them at least something of the spirit of that institution, its respect for exact scholarship and regard for scientific truth. For the schools of engineering and technology in the United States are, and are intended to be, something more than a mere avenue leading to increased money-making

power. They are intended to fit for the responsibilities of citizenship, and, if worthy of the name, their methods of instruction are such as to cultivate independence of thinking and personal responsibility in judgment. Nor are they deficient in that intellectual discipline and culture which constitute a liberal education. Although not specifically organized for original research, their methods of work naturally lead to and encourage it, and during the past quarter of a century they have contributed generously to the advancement of pure science, to which, however, they must always be in debt. As a whole, they represent one of the most important achievements of an age whose chief glory is found in the increase and diffusion of science and its applications.